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RESEARCH AND DEVELOPMENT OF MATERIEL

ENGINEERING DESIGN HANDBOOK

AMMUNITION SERIES

FUZES, PROXIMITY, ELECTRICAL

PART ONE (U)

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AMCP 706-211 (C), Fuzes, Proximity, Electrical, Part One (U), forming part of the Ammunition Series of the Army Materiel Command Engineering Design Handbook Series, is published for the information and guidance of all concerned.

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FOREWORD

The Ammunition Series is part of a group of handbooks covering the engineering principles and fundamental data needed in the development of Army materiel, which (as a group) constitutes the Engineering Design Handbook Series.

Fuzes, Proximity, Electrical comprises five numbered Parts, each of which is published as a separate volume and assigned an Army Materiel Command Pamphlet (AMCP) number. Arrangement into Parts and Chapters, with Chapter titles, is as follows:

AMCP 706-211(C), *Fuzes, Proximity, Electrical—Part One (U)*

- Chapter 1 —Introduction
- Chapter 2 —Philosophy of Fuze Design
- Glossary
- Index

AMCP 706-212(S), *Fuzes, Proximity, Electrical—Part Two (U)*

- Chapter 3 —VHF and UHF Radio Systems

AMCP 706-213(S), *Fuzes, Proximity, Electrical—Part Three (U)*

- Chapter 4 —Microwave Radio Systems

AMCP 706-214(S), *Fuzes, Proximity, Electrical—Part Four (U)*

- Chapter 5 —Nonradio Systems
- Chapter 6 —Multiple Fuzing

AMCP 706-215(C), *Fuzes, Proximity, Electrical—Part Five (U)*

- Chapter 7 —Power Supplies
- Chapter 8 —Safety and Arming Devices
- Chapter 9 —Components
- Chapter 10—Materials
- Chapter 11—Construction Techniques
- Chapter 12—Industrial Engineering
- Chapter 13—Testing

The purpose of these handbooks is twofold: (1) to provide basic design data for the experienced fuze designer, and (2) to acquaint new engineers in the fuze field with the basic principles and techniques of modern fuze design.

These handbooks present fundamental operating principles and design considerations for electrical fuzes and their components, with particular emphasis on proximity fuzes. Information on mechanical fuzes, and other general information on fuzes, is contained in ORDP 20-210, *Fuzes, General and Mechanical.*

As indicated by the Table of Contents, the arrangement of material is primarily topical. This permits ready reference to the area in which the user desires information.

Some subjects are covered in considerable detail, whereas others are covered only superficially. Generally, the amount of coverage is an indication of the state of development of a system. There are exceptions to this, however. For example, although the section on optical fuzing is comparatively extensive, this type of fuzing is not as far advanced as other methods of fuzing. Much of the information in this section, however, is based on an unpublished report. Rather than risk the loss of this information, and to disseminate it more widely, the information is included in these handbooks.

A Glossary is included in which terms that are unique to the fuze field, or that have special meaning in the fuze field, are defined.

References at the end of a chapter indicate the documents on which the chapter is based. They also furnish additional sources of information.

Titles and identifying numbers of specifications, standards, regulations and other official publications are given for the purpose of informing the user of the existence of these documents, however, he should make certain that he obtains editions that are current at the time of use.

Defense classifications are indicated for chapters, paragraphs, illustrations and tables. The degree of classification of the contents of each illustration or table is indicated by the appropriate initial symbol immediately preceding the title. In the case of classified illustrations or tables the classification of the title itself is indicated by appropriate initial symbol immediately after such title.

These handbooks were prepared under the joint direction of the Harry Diamond Laboratories (formerly Diamond Ordnance Fuze Laboratories) and the Engineering Handbook Office, Duke University. Text material was prepared by Training Materials & Information Services, McGraw-Hill Book Company, Inc., under contracts with both of these organizations. Material for text and illustrations was made available through the cooperation of personnel of the Harry Diamond Laboratories. The operation of the Engineering Handbook Office of Duke University is by prime contract with the U. S. Army Research Office, Durham.

Comments on these handbooks should be addressed to Commanding Officer, Army Research Office, Durham, Box CM, Duke Station, Durham, N. C.

PREFACE

Part One of this handbook contains Chapters 1 and 2, with the Glossary and the Index for all Parts. A Table of Contents for all Parts is also included. Chapter 1 introduces the various types of electrical fuzes such as radio and nonradio proximity fuzes and contact fuzes, and traces the development of electrical fuzes from 1941 to the present time. Chapter 2 presents the basic philosophy involved in designing a fuze. Considerations such as countermeasures, encounter geometry, type of warhead, and costs are discussed. The Glossary defines terms that are unique to, or that have special meaning in, the fuze field.

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CHAPTER 1

(C) INTRODUCTION

1-1 (C) TYPES OF FUZES

(U) A fuze is a device with explosive components designed to initiate a train of fire or detonation in an item of ammunition by an action resulting from hydrostatic pressure, electrical energy, chemical action, impact, clockwork action, or a combination of these. There are two broad categories of fuzes: mechanical and electrical. Electrical fuzes are the subject of this handbook. A fuze that in any way requires electrical energy for operation is considered an electrical fuze.

Figure 1-1 is a breakdown of the various types of electrical fuzes. Each major type is briefly discussed in the following paragraphs. Detailed information is contained in the paragraphs given in the figure.

1-1.1 (U) PROXIMITY FUZES

A proximity fuze initiates warhead detonation by sensing one or more of the following target characteristics: presence, distance, direction, and velocity. This is accomplished by the interaction of the sensitivity and sensitivity pattern of the fuze and the characteristics of the target or the target's environment. In many applications, the use of proximity fuzes instead of time or impact fuzes greatly increases the effectiveness of projectiles, bombs, rockets, guided missiles, and other weapons. This increase in effectiveness varies greatly depending on the type of proximity fuze, the weapon in which it is used, and the characteristics of the target. Excluding hard targets, the improvement is generally in the range of 5:1 to 20:1 (Ref. 1).

Proximity fuzes may be classified as either radio or nonradio. The radio types use electromagnetic radiation and operate in the VHF UHF and microwave regions of the RF spectrum. Nonradio proximity fuzes make use of many types of phenomena to sense the presence of a target. Some of these phenomena are electromagnetic radiation in the visible, infrared, or ultraviolet regions; acoustic waves; electrostatic fields; and barometric pressure.

Both radio and nonradio proximity fuzes are further classified as active, passive, semiactive, or semipassive systems. In an active fuze system, the target is illuminated by radiant energy transmitted by the fuze. A small portion of this energy is reflected back to the fuze to initiate the desired fuze action. A World War II Doppler fuze is one example of an active fuze system.

In a passive fuze system, the fuze receives radiation emitted by the target itself. For example, an infrared fuze may operate on the infrared radiation from the not exhaust of a jet aircraft.

Semiactive fuze systems require that the target be illuminated by a friendly source not at the fuze, and the fuze then receives the reflected energy from the target. An example of a semiactive system is one in which a photoelectric fuze operates on the energy reflected by an air target that is illuminated by a friendly searchlight.

In semipassive fuze systems the fuze receives reflected energy from a target that is illuminated by a source not under control of either friend or foe. For example, radiation from the sun could be used to operate a semipassive photoelectric fuze system. The fuze may function because of obscuration of background radiation when the target enters the field of view of the fuze or because of reflection of radiation by the target towards the fuze.

1-1.2 (U) CONTACT FUZES

Although proximity fuzes possess many advantages over contact fuzes, there are many applications in which detonation of a round on or shortly after contact with a target is desirable. High explosive antitank (HEAT) rounds function on contact with a target. To inflict maximum damage, these rounds require that detonation occur within a few microseconds after contact with the target. The requirement that fuze action occur in such a short

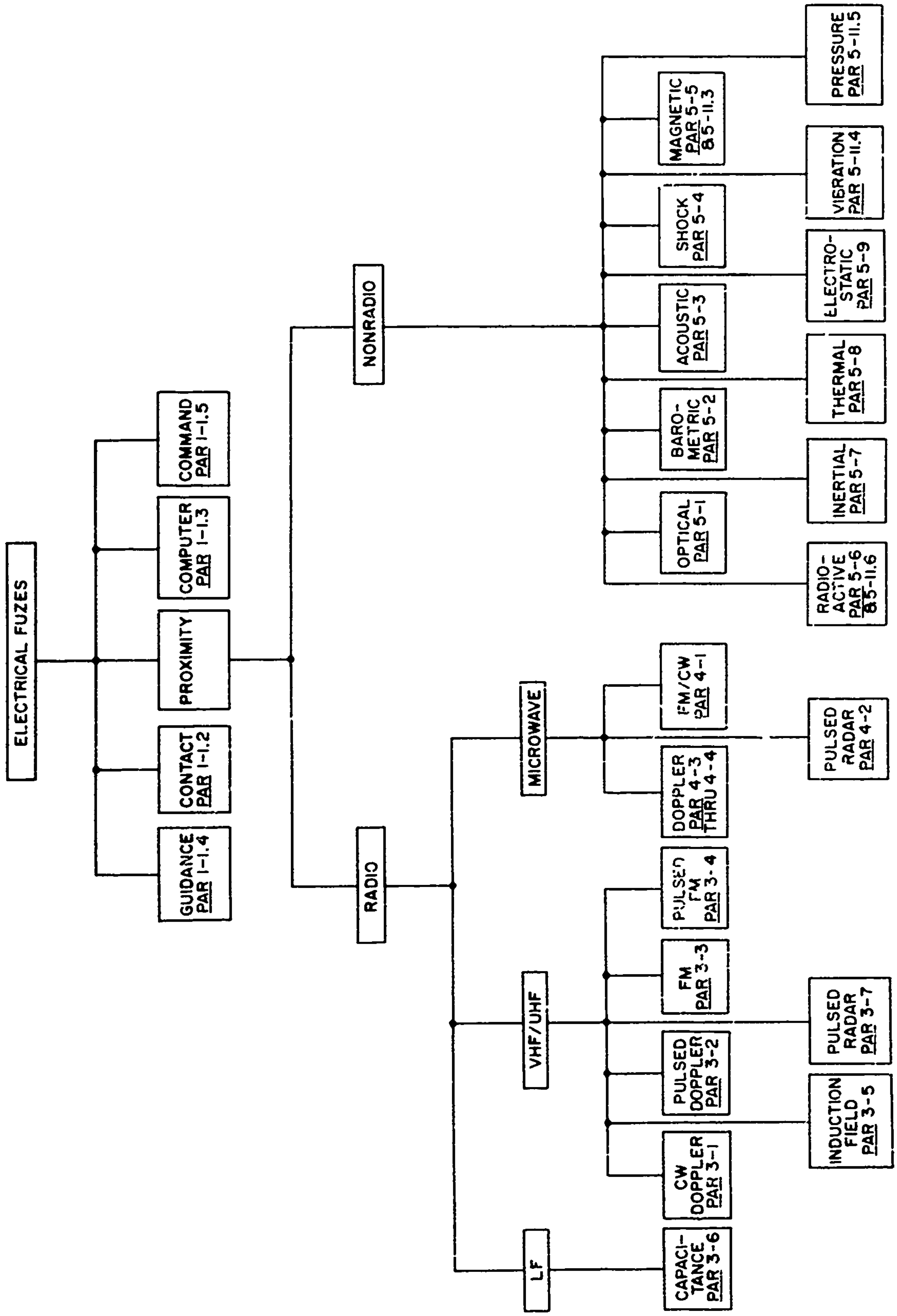


Figure 1-1 (C). Types of Electrical Fuzes (U)

period of time eliminates any mechanical fuzing scheme. One type of electrical fuze proposed for this application contains a firing capacitor that is charged by a magnetic impulse generator when the round is fired. Upon impact with the target, a pair of contacts at the nose of the fuze closes and discharges the capacitor through the detonator.

Another type, which is in present use, employs a piezoelectric crystal mounted in the nose of the round. A wire connects the crystal to the detonator, which is mounted in the base of the round. Upon impact, the electrical energy that results from deforming the crystal causes the detonator to fire.

1-1.3 (C) COMPUTER FUZES

Computer fuzes compute the optimum time for warhead detonation from information provided by the missile target seeker. They have been considered for use in a number of guided missile applications where omnidirectional warheads are employed. With this type of warhead the optimum point of detonation occurs at or near the point of closest approach between the missile and target. Fixed angle proximity fuzes generally do not indicate the optimum point of detonation for omnidirectional warheads.

Computer fuzes have not been used extensively up to the present time. Although accurate computer fuzes could probably be developed, they would be only as accurate as the target seeker from which they obtain information. At present, the accuracy of missile target seekers is not sufficient to obtain the full benefits of computer fuzing.

One present-day missile, the Bomarc, uses a computer fuze. It is used, however, as a secondary fuze and operates only when the primary radio proximity fuze is inoperative because of malfunctioning or enemy countermeasures.

1-1.4 (U) GUIDANCE FUZES

Guidance fuzes derive all information for fuzing action from the missile guidance system. They contain no transmitter or receiver and are essentially computers that utilize guidance signals for the operation. Guidance fuze systems require no microwave antennas or plumbing, generally require less power than missile proximity fuze systems, but are no better than the missile guidance system with respect to clutter and countermeasures.

1-1.5 (U) COMMAND FUZES

A command fuze functions as a result of intelligence transmitted to it from a remote control station, usually a ground radar. In most instances a computer, associated with the ground radar, determines the optimum time to trigger the fuze. Only a few components are required in the missile, because the fuzing problem is solved by the ground computer.

1-2 (U) FUZE REQUIREMENTS

In many instances, fuze requirements differ considerably from those of conventional electronic equipment. For example, a fuze may be stored for as long as 20 years and then be used for only a few seconds before it is destroyed by the detonation it initiates. In many cases, no maintenance or preflight checkout of the fuze is permissible.

The fuze designer must consider reliability in a somewhat different manner than the conventional equipment designer. Normally, the fuze designer needs "one-shot" reliability, whereas the designer of conventional equipment may consider "mean-time-between-failures" to determine the reliability of his equipment.

Safety requirements for fuzes are extremely stringent because many fuzes contain explosive components. Fuzes must be safe during manufacturing, storage, and handling. During operational use, a fuze that prefunctions may cause injury or death to friendly personnel, and severe damage to equipment. Compatibility of materials used in fuze construction must also be considered. Particularly, the behavior of explosives with adjacent materials must be known before production begins. A reaction between noncompatible explosives and materials might result in detonation of the fuze during storage, causing loss of life and equipment.

Counter-countermeasures requirements for fuzes are somewhat different than for many conventional electronic equipments. For example, the designer of a search-type pulsed radar may incorporate counter-countermeasures controls in the equipment. These controls would be used by the operator only when enemy countermeasures are encountered. At all other times, the equipment can operate at optimum gain, sensitivity, power output, etc. When designing a proximity fuze, however, the fuze designer must assume that the fuze will be jammed at all times. This means that compromises may have to be made with respect to major fuze parameters to eliminate or reduce the effects of enemy countermeasures.

1-3 (C) HISTORY

(U) Electrical fuzes have been used in many varied fuzing applications since about 1940. The purpose of this section is to present factors considered during the evolution of electrical fuzes. Such factors include: why development of the various types of fuzes was started; present status of various programs; and why certain projects were discontinued. Because the proximity fuze represents the most sophisticated, and by far the most widely used type of electical fuze, it is the type discussed in greatest detail.

The history of proximity fuzing may be divided into three periods: (1) World War II, the period during which the basic proximity fuze was developed; (2) the end of World War II to the Korean War, the period during which many new methods of proximity fuzing were investigated, and guided missile fuzing was started; and (3) Korean War to 1960, the period during which considerations of the use of nuclear warheads created many new and difficult requirements for fuzing.

This chapter points out many of the highlights of these periods. A detailed history of World War II fuzing is given in References 2 and 3, a detailed history from 1953 to 1960 is given in Reference 4. Much of the information in this section is based on these references.

1-3.1 (U) WORLD WAR II

Development of poximity fuzes was started in 1940. Early in the development program the Army was assigned the responsibility for fuzing nonrotated, or fin-stabilized, projectiles and the Navy was assigned the responsibility for rotated, or spin-stabilized, projectiles. The work on nonrotated projectiles was performed at the National Bureau of Standards under sponsorship of the National Defense Research Committee (NDRC). The development of rotated projectiles was carried on at the Johns Hopkins University Applied Physics Laboratory.

During World War II, many types of proximity fuzes were investigated. The most important of these were acoustic, pressure, electrostatic, optical, and radio.

The acoustic fuze operates on the noise generated by an aircraft in flight. It appeared that a cheap and reliable antiaircraft fuze could be designed and produced, provided that noise generated by the missile carrying the fuze did not introduce complications that could not be tolerated. Tests conducted to evaluate the noise generated by missiles in flight showed that the self-noise of the missile exceeded the noise level produced by an air target at distances at which proximity operation was desired. Because the velocity of sound was another major limitation of an acoustic fuze, particularly in applications involving high-speed missiles against high-speed aircraft, the development of an acoustic fuze was abandoned.

To explore the possibility of producing air-burst bombs by means of barometric or pressure-operated devices, a barotimer, which was a combination barometric and time device, was investigated. This device continually measured the barometric pressure to determine the altitude at which a bomber was flying and then set a time fuze to the time required for a bomb to fall the required distance to the target. Although the barotimer proved reliable in laboratory tests, no field tests were conducted. It was concluded that burst heights would be too variable because of inherent limitations in predicting atmospheric pressure and probable lack of knowledge of atmospheric pressure over the target.

A somewhat unique pressure-activated device was developed by the British. It was called the No. 44 Pistol fuze and contained a pressure-sensitive diaphragm that caused detonation when subjected to a sudden increase in pressue. Air burst was obtained by dropping several bombs, each containing a Pistol fuze, in a stick or train. The first bomb exploded on contact with the target, and the blast effect caused the other bombs to burst in the air. This method, however, was only about half as effective as radio proximity fuzing, and little effort was made to develop this type of fuze any further.

During this same period, considerable research was carried on concerning the possible use of electrostatic methods to produce air bursts, particularly for antiaircraft applications. This method of fuzing was appealing primarily because of its simplicity. Operation of an electrostatic fuze depends upon the electrical charge on the target or missile, or on both. At the time, it was concluded that charges on an aircraft in flight and on the missile were too variable to insure reliable proximity operation. Consequently, work on this program was also abandoned.

A considerable amount of research and development during World War II was devoted to optical fuzing methods. A photoelectric optical fuze was developed by the British very early in the war, and their work provided a starting point for American developfent. A reasonably successful passive photoelectric fuze was developed in this country in 1942.

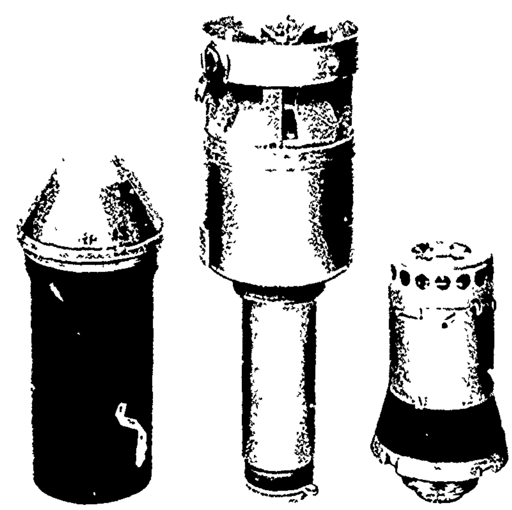
Photoelectric fuzes were simple, and the burst position with respect to the target could be controlled very accurately. This fuze, however, had two major limitations: (1) its operation was restricted to daytime; and (2) it could be prefunctioned by the light from the sun (see Ref. 3).

Similarly, studies of infrared optical fuzing systems were also initiated and halted during this period. The main reason for discontinuing research in this area was because IR detectors available at that time were too slow, or too insensitive, for fuzing applications. This fact, coupled with the apparent practicability of radio proximity fuzing, resulted in the abandonment of infrared fuzing.

In October 1943, all other types of proximity fuzes were shelved in favor of developing the radio proximity fuze. Although this type of fuze was more complicated than the others investigated, it possessed two important advantages: (1) it provided performance day or night under a variety of operating conditions; and (2) it could be used against any target that reflected radio waves. The second advantage meant that a single basic principle could be used for both air-target and ground-target applications.

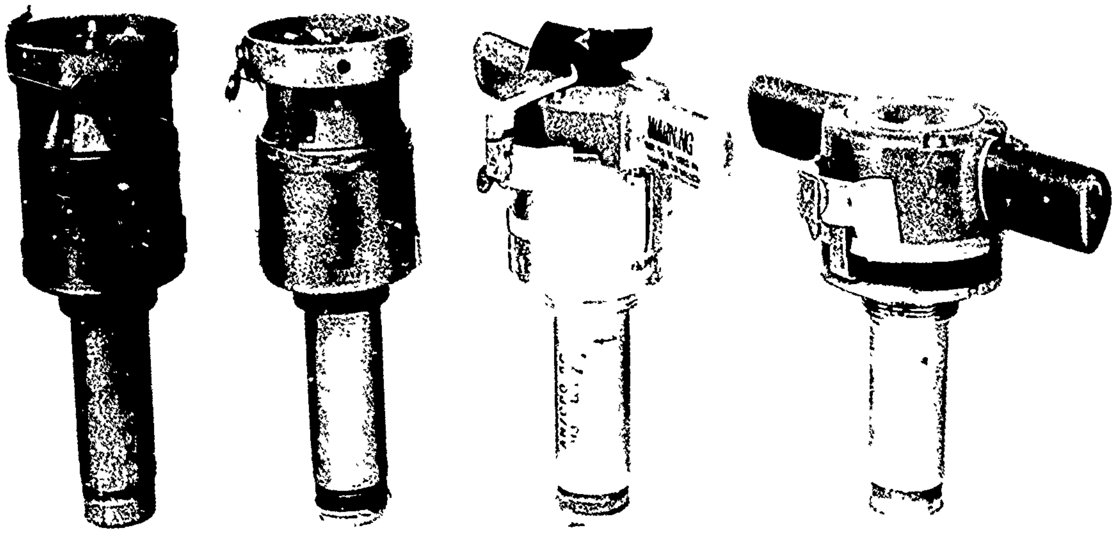
During World War II, radio proximity fuzes were developed, at the National Bureau of Standards, for bomb, rocket, and mortar applications. All of these fuzes utilized the Doppler effect, i.e., the difference in frequency between a transmitted wave and a received wave due to relative motion between the fuze and target. Figure 1-2 shows typical rocket fuzes developed during this period. The T5 fuze was used with air-to-air rockets, and was the first radio proximity fuze developed. A slightly modified version of this fuze, designated the T6, was designed for ground-to-ground rocket firing. Both fuzes were powered by dry batteries.

The T2004 rocket fuze was an air-to-ground weapon. It was powered by a wind-driven generator to eliminate problems associated with dry batteries. The T2005 rocket fuze was also powered by a wind-driven generator and could be used against both air targets and ground



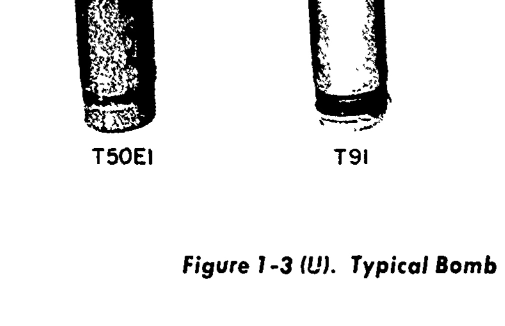
T5 T2004 T2005

Figure 1-2 (U). Typical Rocket Fuzes Developed During World War II



T50E1 T91 T51 T82

Figure 1-3 (U). Typical Bomb Fuzes Developed During World War II



T132 T171 T172

Figure 1-4 (U). Typical Mortar Fuzes Developed During World War II

targets. A switch mounted on the fuze was used to select the desired application.

Typical bomb fuzes developed during World War II are shown in Figure 1-3. All of these were powered by wind-driven generators. The T50E1 and the T91 used the bomb itself as the fuze antenna. The T51 and T82 used transverse antennas.

Figure 1-4 shows radio proximity mortar fuzes developed during the war. The T132 fuze contained printed circuits. This was one of the first applications of printed circuit techniques. The T171 fuze was similar to the T132, except that it employed the more standard circuit assembly techniques. Both of these fuzes used the mortar projectile itself as an antenna. The T172 mortar fuze used a separate loop antenna. All fuzes were powered by wind-driven generators.

Proximity fuzes developed during World War II had a number of shortcomings. At best, the fuzes had a reliability of about 70% to 90%; in rain or other adverse weather conditions they were much worse. Shelf life was limited to about six months to five years because of inadequate sealing methods, and the temperature range over which they could operate was limited, particularly for fuzes using batteries. The counter-countermeasures characteristics of the fuzes were only fair by present day standards. No special counter-countermeasures circuits were incorporated in fuzes and the radiated power was low.

Radio proximity fuzes saw somewhat limited operational use during World War II, primarily because they were introduced into action very late in the war. Thus, a thorough analysis of the effectiveness of the fuzes was not possible. The general reaction, however, was favorable. They proved highly effective in defending the fleet against Japanese attacks, and in defending London against buzz bombs.

1-3.2 (C) WORLD WAR II TO KOREAN WAR

During the years following World War II, many significant advances were made in the proximity fuze field. The radio proximity fuze was greatly improved; many new types of fuzes, including nonradio, were developed; and fuze reliability was greatly increased by the use of improved components and materials, better production methods, and multiple fuzing systems.

Immediately after the war, work was started to improve the CW Doppler radio proximity fuze. Loop antennas were developed to permit fuze operation in missiles during the burning of the rocket propellant. Prior to the development of loop antennas the rocket body was used as the fuze antenna. Ionized gases caused by afterburning had the effect of continually changing the effective length of the antenna and fuze performance was, therefore, quite erratic and unreliable.

Sophisticated amplifiers were developed for use in bomb, rocket, and mortar fuzes. These amplifiers provided improved protection against countermeasures, improved reliability in the presence of noise caused by vibration, and more uniform function heights under varied field conditions.

Pulsed Doppler fuzes were also investigated during this period. By pulsing the conventional CW Doppler fuze, higher power output and definite range cutoff, a distance beyond which the fuze cannot "see," were obtained. This greatly improved the counter-countermeasures capabilities of the Doppler fuze. Because of problems associated with pulsed Doppler fuzes, particularly in designing a suitable pulse modulator, work was discontinued. The work performed during this period, however, was the basis for the pulsed Doppler fuze that was developed many years later.

In 1946, work was started on guided missile fuzing. At the very beginning of the guided missile fuze program it was obvious that it was no longer possible to use a large number of small explosive charges that would burst in the general vicinity of a target. It was now necessary, because of the high cost of guided missiles and the limited fire power of launchers, to insure that every missile that passed within lethal range of the target effected maximum target damage. This required a fuze with a great deal more intelligence than the radio Doppler fuze, and one with a highly directive antenna pattern to resolve the target with greater precision. It was also required that the fuze withstand the vibrations that would be encountered in guided missiles.

These requirements led to the development of frequency-modulated microwave fuze systems. A typical guided missile fuze and some of its major components are shown in Figure 1-5.

The first FM microwave system developed, the Alpha system, was intended for use against air targets. This system is still in use today. By operating in the microwave region, precise antenna patterns were obtained and, therefore, precise burst positions. Operation at microwave frequencies also permitted the use of a very narrow conical antenna pattern that could be seen by the target for only a short time during intercept. This made countermeasures very difficult. The combination of a high carrier frequency and frequency modulation resulted in a Doppler signal far above the microphonic frequency region, thus making the fuze insensitive to vibration.

An extremely difficult problem in the development of this fuze was to design a highly directive multielement antenna array that did not protrude from the missile skin. This problem was solved by using multiple slot antennas coupled directly to waveguides within the nose of the missile. This development has since become standard practice in microwave guided missile fuzing.

Early in the guided missile fuze program it became apparent that problems posed by air targets and ground targets differed to such an extent that each required different approaches and different solutions. The basic requirements

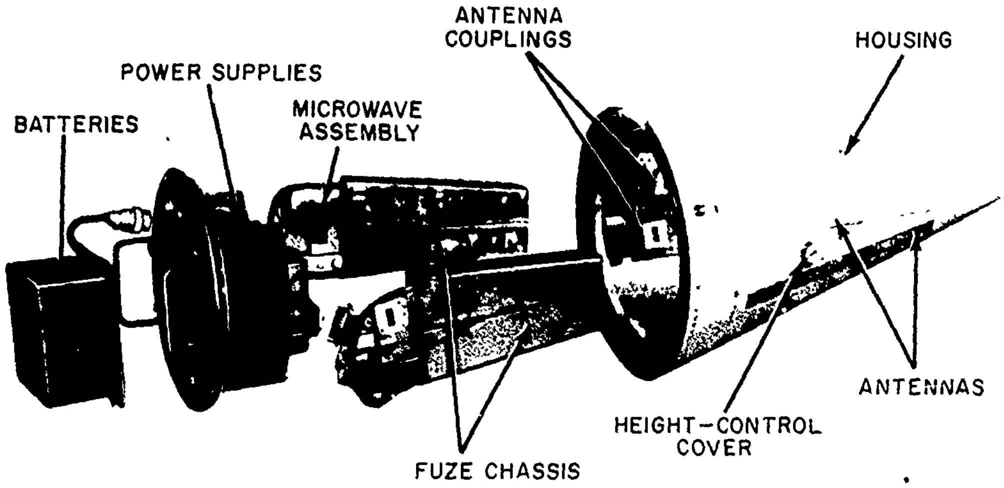


Figure 1-5 (C). Typical Guided Missile Fuze (U)

of a high degree of intelligence, high antenna directivity, and immunity to vibration applied to ground target fuzes as well as air target fuzes. The tactical use of the two types, however, differed considerably. Whereas the ground target fuze approached an essentially plane and infinite surface, and was intended to fire at a fixed height above it, the air target fuze was intended to fire when it came into a certain class of prescribed geometric relations with a target of limited size approached from a wide variety of relative bearings.

Two methods of fuzing ground target missiles were developed. The first, called the Delta fuze system, is a microwave FM system, similar to the Alpha system. The Delta system has proven successful and is used in a number of pesent-day missiles. Because of its low power output, however, it cannot be used in applications requiring very high burst heights. For this reason, pulsed radar fuzing systems, which are capable of high peak power output, were developed. Like the Alpha and Delta fuze systems, pulsed radar systems proved very successful and are in use today.

At the close of World War II, it was decided to reexamine nonradio fuzing methods. This work was performed concurrently with the further development of radio proximity fuzes. One of the primary reasons for this decision was the desirability of obtaining a broad background of information and experience in the nonradio field so that the optimum fuze, either radio or nonradio, could ultimately be designed for any specific fuze application. Also, it was no longer a secret that this country had developed a radio proximity fuze. Therefore, from a counter-countermeasures standpoint, it was desirable to develop fuzes that depended on many types of phenomena for their operation.

A great deal of work was done on optical (infrared and ultraviolet), electrostatic, and acoustic fuzes. Work was also started on various types of antivehicular mine fuzes. In addition, a fuze which recognized the shock wave generated by a supersonic aircraft was investigated. Although a number of successful tests were run on all of these fuzes, there were still problems to be solved before they could be considered reliable ordnance weapons.

During this period, significant advances were made in component development. Among these were semiconductor devices, a special klystron for guided missile fuzing applications, thermal batteries, and smaller and more reliable components.

Possibly the most impotant development in fuze components was the thermal battery. This is a reverse-type, solid electrolyte battery that is activated by a heat source contained within the battery. It became obvious during World War II that fuzes must be sealed to permit storage for long periods. This immediately eliminated wind-driven generators for power suppiies. Dry batteries and liquid-electrolyte batteries used during the war were also eliminated because the dry batteries had a short shelf life, and the liquid electrolyte batteries could not operate at the low ambient temperatues specified for the new fuzing applications. The thermal battery solved both of these problems. It has excellent shelf life, and because heat is generated within the battery itself, the low ambient temperature problem was solved.

1-3.3 (C) KOREAN WAR TO 1960

During this period, radio proximity fuzes for bombs, rockets, and mortars were greatly improved; new types of radio proximity fuzes were investigated; nonradio proximity fuzes were further developed; and the development of guided missile fuzes was pursued with great vigor. This was the beginning of the era of ballistic missiles and nuclear warheads. Fuzes of extremely high reliability and very precise burst heights were required.

With the advent of nuclear warheads small enough to be carried in guided missiles, it appeared at first that precision burst heights would no longer be required. The great damage capabilities of these warheads made it obvious that any air burst in the vicinity of a target would cause tremendous damage, and emphasis was placed upon extremely high reliability rather than burst height accuracy. After a short time, however, it became apparent that precise burst heights were more necessary than ever. In many tactical situations, precise control of warhead detonation is desirable to provide close support of friendly forces in the field. Also, nuclear tests indicated that there is an optimum point of nuclear warhead detonation for maximum destructiveness. A silght increase in burst accuracy of a nuclear warhead can result in a great increase in destruction.

Unquestionably, extremely high fuze reliability was of paramount importance in nuclear warhead applications. A reliability of .99, or greater, was specified for most missile fuzes being developed. Cost considerations for the missile and warhead alone dictated this requirement. Also, the damage that might result from premature detonation of a nuclear warhead made it mandatory that the probability of prefunction be less than 1 in 100,000.

Improved versions of the microwave FM and the pulsed radar fuze systems were used for nuclear warhead applications. The difficulty of building 99% reliability into these fuzes was recognized immediately. Therefore, in many applications it was decided to use dual fuzing systems. When two independent fuzes are connected in parallel, and each has a proper function reliability of 90%, the reliability of the combination with regard to dudding, assuming that all malfunctions are duds rather than earlies, is 99%.

In some applications, two completely dissimilar fuzes were used. Besides having greater reliability, this provided additional countermeasures protection.

A new microwave FM fuzing system, called the Cobra system, was also developed during this period. In contrast with the other microwave FM systems, it employed nonperiodic modulation, eliminating the problem of range ambiguity and, by spreading the emitted energy over a wide frequency band, greatly enhanced the counter-countermeasures capabilities of the system.

In addition, two proximity fuzes were developed for somewhat unique applications. These fuzes, the induction field fuze and the capacitance fuze, were designed to operate in very close proximity to a target. For example, in certain applications, it might be desirable to have a nuclear warhead detonate at the ground instead of in the air. Upon impact, however, the nuclear warhead might become deformed and function improperly. To prevent this, these fuzes through proximity action detonate the warhead a few inches to a few feet above the ground.

Development of nonradio proximity fuzes also continued during this period. Barometric fuzes and infrared fuzes were developed to the point where they were tested in operational missiles. Although significant advances were made in applying electrostatic fuzes to mortar projectiles, the problem of obtaining proper electrostatic fuze operation in inclement weather still remained. Work on acoustic and shock fuzes was terminated when it became apparent that they would be ineffective against very high-speed targets.

A great amount of work was done on antivehicular influence fuzes for mines. Among the types of fuzes investigated extensively were: radioactive; pressure; vibration; and magnetic. A number of these fuzes, particularly those using both magnetic and vibration principles, proved reasonably successful. There were still problems to be solved, however, before influence fuzes for mines became a production item.

Component improvements continued along with fuze development. Transistors were improved to the point where an all-transistorized mortar fuze was developed; thermal batteries capable of producing 4 or 5 amperes up to 28 volts, and 150 millamperes up to 500 volts were developed; and new and improved microwave components became available. Also, a special klystron, the R-1B, was perfected for microwave FM fuze applications.

A new problem now arose in the fuze component field. What would be the effect of nuclear radiation on various types of components? Special groups were set up to study this problem. The characteristics of many components, particularly some semiconductor and magnetic devices, were severely altered by nuclear radiation. This problem is still being studied by a great many military and nonmilitary organizations.

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CHAPTER 2

(C) PHILOSOPHY OF FUZE DESIGN

2-1 (U) INTRODUCTION

This chapter discusses the basic philosophy and considerations involved in the design of proximity fuzes. Some of the problems that will probably be encountered by the fuze designer are also pointed out. Methods of solving these problems are given in other sections of the handbook.

2-2 (C) REQUIREMENTS FOR ANY FUZE

(U) Fuzes are designed for use with various groups of ammunition items. For example, they may be used with artillery projectiles, bombs, mines, rockets, and guided missiles. Each of these groups has its own set of tactical requirements and operational environments that govern the design of the fuze. Within each group, a fuze is usually designed for a specific application: e.g., a guided missile fuze or a rocket fuze may be designed for use against air targets or for use against surface targets. Considering the diversity of fuze applications, the probability of developing a universal fuze that can be used in all fuzing applications is extremely remote.

Generally speaking, however, the requirements for any fuze, regardless of its application, are (1) it must be safe; (2) it must recognize the proper time for detonation and must initiate detonation at that time; and (3) it must be reliable. The degree of safety, accuracy, and reliability is dictated by the specific application of the fuze.

2-2.1 (U) SAFETY

A fuze is unacceptable if it is not safe during manufacturing, during storage and handling, and during operational use. This is a fundamental concept of fuze design, and it is not subject to compromise. An unsafe fuze can become a subtle weapon of the enemy.

The safety and arming device in many fuzes contains sensitive explosives. The explosives are usually installed when the fuze is manufactured or shortly thereafter. If a fuze becomes armed during normal handling and transportation, the danger to the handler may be great. Should the fuze become armed when it is installed in its associated ammunition item, a condition of still greater danger exists.

There are two major safety requirements for all U S. fuzes: (1) functioning of the detonator alone must not initiate subsequent explosive train components; and (2) the primary fuze safety and arming device must not depend upon cocked springs, explosive motors, or other types of energy stored prior to launching. This is the "no stored energy" concept. Exceptions must be approved by the using services.

All fuzes must be deemed safe for operational use, but the safety requirements for some types of fuzes are more stringent than others. No fuze can be declared absolutely safe. It is logical to assume, however, that the safety requirements for a missile or artillery projectile carrying a nuclear-type warhead will be more stringent than those for a conventional mortar round.

New devices must be thoroughly tested and proven. It is sometimes possible to use safety devices that have proven successful in the past. Environmental factors vary from application to application, however, and some redesign will probably be necessary. Still, the fuze designer's problem will be simplified because the adequacy of the basic design has already been proven.

2-2.2 (U) DETONATION

To design a proximity fuze that will detonate "proper," the fuze designer must develop a fuze that recognizes and processes certain characteristics of the target or the target's environment. To determine the proper conditions for detonation, the fuze designer must know the terminal ballistic characteristics of the projectile in which the fuze is to be used, type of encounter, nature of target, operational environment, and the target's military significance.

2-2.2.1 (U) Terminal Considerations

The requirements for a surface target proximity fuze differ considerably from those for an air target proximity fuze. The primary function of a surface target fuze is to cause detonation at a specified height above ground. An air target fuze is required to cause detonation when a target is within a specified distance from the fuze.

Major considerations for surface target applications are height of burst, type or types of warheads to be used and required accuracy. Each of these, to a large extent, determines the type of fuze that can be used. For example, certain types of warheads require a burst height of about 25,000 ft for maximum effectiveness. Normally a high degree of accuracy is not required for this type of operation. Considering the present state of the art, a barometric-type proximity fuze would be a logical choice for this application. Radio-type proximity fuzes probably would not have the required loop-gain capabilities to operate reliably at this height.

If a high degree of accuracy is specified, microwave fuzes are generally preferred over VHF/UHF fuzes because of the precise antenna patterns that can be obtained at microwave frequencies.

In some surface target applications, different types of warheads might be used with the same missile. Because the warheads may have different burst characteristics, the fuze designer must decide whether to design a special fuze for each warhead or to design a multipurpose fuze that can be used with several of the warheads. Although a special fuze for each warhead would probably be somewhat simpler than a multipurpose fuze, it should be avoided if possible. If special purpose fuzes are used, separate development programs for each may be required. The cost of the fuze program would, no doubt, increase significantly. Special fuzes would also increase problems involving flight testing and logistics. More flight tests would be required, and more fuzes for a particular weapon would have to be stockpiled.

The solution to the air target fuzing problem is generally more involved than that of the surface target case. The fuze designer requires a thorough knowledge of the type of target, the fuze-target encounter geometry, and the warhead characteristics.

Typical target characteristics that must be known are speed, shape, size, maneuverability, and payload. Speed, shape, and size are probably the most important. Because the fuze is to operate only in the presence of a proper target the nature of the return signal from the target must be known. For radio-type fuzes, the return signal is an electrical representation of the target. It contains such information as Doppler frequencies generated by approach velocities, and signal buildup and time duration due to target size and relative velocity. From these data, the fuze designer must design a fuze that responds to the proper target.

Target maneuverability must be known to determine the encounter geometry. It is also important in determining miss distance. The payload must be known, because it may be the most vulnerable part of the target.

A study of fuze-target encounter geometry is difficult. Many variables make computation, tabulation, and analysis a tedious and time consuming task. There are encounter simulators available, however, and the fuze designer should make use of these devices whenever possible. The problem involves not only missile and target trajectories, but also the characteristics of the missile warhead. Different types of warheads have different propagation characteristics. A typical fragmentation-type warhead produces a side spray of high velocity fragments approximately normal to the missile axis. Hence, the fuze is required to have a relatively precise sensing pattern to utilize the concentrated-fragment beam to best advantage.

Some types of warheads have spherical fragmentation patterns and, therefore, require less precise fuzing. Another type, the cluster warhead, ejects a number of small bombs or bomblets perpendicular to the axis of the missile. This results in a slowly expanding ring of bomblets, each with sufficient explosive capability to destroy a target.

2-2.2.2 (U) Recognizing Proper Time for Detonation

There are many phenomena available that may be used to recognize the proper time or point of detonation. These phenomena are given in Chapter 1 and are discussed in detail in later chapters. Each has certain advantages and disadvantages with respect to a particular application. At the present time, most proximity fuzes, particularly those considered for guided missile and bomb applications, are of the radio or barometric type. The reason for this is simply that at the present state of the art, these types appear to be the best that can be made. For many other types of proximity fuzes, for example, electrostatic, inertial, etc., sufficient data are not yet available to determine just how effective they may be; or they cannot meet certain technical requirements specified by the military. It is conceivable, however, that with advances in the state of the art, these types may become practicable for many fuzing applications.

A number of types of fuzes may appear feasible for a particular fuzing application. The fuze designer must normally base the decision as to what type of fuze system to use on the availability of the system and the desirability of the system. Unfortunately, time and money many times prohibit the fuze designer from exploring untried methods of fuzing. He must, if possible, use a previously developed fuze if it fits his application. In these days of telescoped development and production programs, this is particularly true.

If no existing type of fuze appears suitable for a particular application, the fuze designer must explore many possibilities to reach a decision as to the type of fuze to use. He must be wary, however, if his selection of a fuze is based upon its immediate theoretical feasibilty. The problems associated with operational faults, production difficulties, and new components cannot be dismissed lightly.

2-2.3 (U) RELIABILITY

The problem of achieving reliability is one that constantly faces the fuze designer. The fuze is an ammunition item; that is, it must be ready for instant and automatic operation at any time under any environmental conditions. Normally, the military specifies the required reliability for a particular fuze. It will vary, depending upon the particular fuze application. A 90% reliability may be specified for a mortar or conventional bomb fuze; for fuzes used with nuclear weapons, 99% or greater is typical. Theoertically, 100% reliability is desirable in all fuzes. Obviously, however, the present state of art does not permit this

How does the fuze designer go about building reliability into a fuze? First of all, reliability is not an after thought, it must be considered from the very beginning of a fuze development program. Reliability will be affected by every decision the fuze designer makes, from the choice of circuits and components to the container in which the fuze will be stored. Every detail of design, whether electrical or mechanical, affects reliability. Obviously, using proven circuits and components where possible will enhance reliability. It is sound practice to use a system that requires a minimum number of components consistent with the required performance of the fuze, provided that the components are not operated too near to their ratings.

In the past, many radio proximity fuzes have been built that had reliabilities of the order of 90%. In many present day applications where nuclear warheads are used, however, reliabilities of greater than 99% are the rule. The fuze designer should realize that, no matter how attentive he is to his basic design and selection of components, it is economically unfeasible, if not nearly impossible, to design one fuze with a reliability of 99%. The state of the art simply has not progressed that far. The present practice is to use dual fuze systems so connected that if either fuze functions properly, a firing signal will be sent to the warhead. By connecting two fuzes in parallel, with each fuze having a reliability of 90%, an overall reliability of 99% is obtained. Most present-day guided missiles use this method to achieve high reliability.

Reliability improvement frequently increases the cost of a fuze. There are many criteria upon which the decision of whether or not to improve reliability must be based. User safety, tactical efficiency, and cost are just a few. Sometimes the decision is rather obvious. For instance, assuming that a fuze meets the specified military reliability, it would probably be impractical for the fuze designer to double the cost of the fuze to increase its tactical efficiency by only a few percent. Other decisions, particularly with respect to safety, are not that simple.

Unlike most other electronic equipment designers, the fuze designer is concerned with a device that will operate reliably only once or at most a relatively few times if it is to be tested. Reliability cannot be proven on the basis of many devices operating for long periods of time. In many cases it is impossible to test a sufficient number of fuzes to prove their reliability. This is particularly true in guided missile applications. Therefore, the fuze designer must base reliability predictions to a great extent on the basic design of the fuze and the reliability of the components used. Also, data obtained from laboratory and field tests must be utilized to prove the reliability prediction.

2-2.4 (C) OTHER FUZE REQUIREMENTS

Besides safety, proper detonation, and reliability there are other factors that must be considered when designing a fuze. Among these are environment, countermeasures, compatibility of fuze and associated weapon, human engineering, production, and costs.

2-2.4.1 (U) Environmental Requirements

Fuze environment is the aggregate of all environments that affect a fuze during its lifetime. These environments are experienced throughout transportation, handling, storage, checkout (if required), and operational use. Shock, vibration, temperature variation, and nuclear radiation are just a few of these environments. Most fuzes encounter the same types of environments during storage, handling, and transportation. That is, they might be exposed to temperature and humidity variations, fungus, rain, corrosion, sand, and dust; or they may be dropped, rolled, or tumbled. In operational use, however, the type of environments that a fuze may encounter are governed to a large extent by the characteristics of the weapon with which it is used. For example, an artillery projectile fuze is subjected to severe shock when it is fired from a gun. A guided missile fuze, however, is not subjected to this type of shock at launching but encounters severe vibration due to propulsion and aerodynamic force.

The military normally specifies the environments to which a fuze will be exposed. The fuze designer's job is to apply design techniques that will protect the fuze from these anticipated environments. To do this, the designer must understand the nature of the environments and their effect on materials and components. He must also consider the effects of combined environments that the fuze may encounter during its lifetime.

Nuclear environments have been of particular concern during the last few years. When considering nuclear environments, the fuze designer must ask two questions: (1) is there a high probability that the fuze will be exposed to this type of environment, and (2) will a high penalty be paid if the fuze does not operate satisfactorily because of the environment? The answer to one or both of these questions is likely to be in the negative for hand grenade fuzes and for short range surface-to-surface missile fuzes. For long range surface target guided missiles, however, particularly in their terminal flight phase, and for air target guided missiles, there is both a high probability of encountering a nuclear environment and a high penalty for failure.

It should be noted that the radiation aspect of a nuclear environment is of prime concern. In any case where other features of the nuclear environment, such as severe shock and heat, are present, it is likely that the entire missile will be destroyed or rendered inoperable; hence, it is of no consequence to design the fuze to withstand these other environmental features.

The possibility of a fuze encountering a nuclear environment should not cause the designer to preclude the use of transistors and other solid state devices. No doubt in many instances the characteristics of these devices are greatly affected by nuclear radiation. In a certain test, one characteristic of a transistor changed almost 800%. During the same test, however, a characteristic of an electron tube used quite often in fuze circuits changed about 180%. In both cases, these changes would probably have caused a fuze to malfunction. Therefore, using tubes instead of transistors is not always the solution to the radiation problem. The fuze designer must attempt to design circuits, using either electron tubes or transistors, capable of operating in a nuclear environment.

The fuze designer should keep in mind that there are groups whose main function is to study nuclear vulnerability. In many instances, they will be able to aid him in solving his radiation problems.

2-2.4.2 (C) Countermeasures

The fuze designer must consider enemy countermeasures from the very beginning of a fuze development program. Counter-countermeasures design normally cannot be separated from the design of the fuze itself.

Countermeasures and counter-countermeasures involve the fields of intelligence, security, the technical art, and economics. As the technical art of fuzing grows in scope, counter-countermeasures versus countermeasures becomes primarily an economic battle. As was pointed out earlier, most present day proximity fuzes are of the radio type. The fact is widely recognized that any system that depends upon reception of electromagnetic energy for operation can be jammed. Whether or not jamming a fuze is feasible depends upon various fuze characteristics, the special circumstances of fuze operation, and many other factors. If the enemy was able to blanket an area with extremely large quantities of power over the entire radio-frequency spectrum, no radio-type system could operate properly. Obviously, however, the cost to the enemy to do this would be prohibitive. The fuze designer, therefore, can assume that this is unfeasible.

To what extent should counter-countermeasures features be incorporated into a fuze? Many factors, such as the weapon on which the fuze is used, cost, schedules, complexity, space, enter into this decision. Generally speaking, the fuze should be made as immune to enemy countermeasures as practicable within the limitations set forth by the above factors. For example, it would probably be unrealistic to incorporate a new counter-countermeasures feature in a conventional artillery projectile fuze if, by so doing, the cost of the fuze would be greatly increased. The cost of the fuze might become prohibitive with respect to the weapon with which it is used.

It may be very desirable, however, to invest extra time and funds to incorporate sophisticated CCM features into guided missile fuzes. The cost of a guided missile is great enough that a more expensive and more sophisticated fuze can be tolerated. Also, because of this high cost of guided missiles and because of the limited fire power of missile launchers, missiles will probably not be fired in barrages. Therefore, everything must be done to ensure that each missile performs its intended function.

With respect to guided missile fuzing, it should be noted that although all of the missile system designers have countermeasures problems, the fuze designer's problem is probably the most severe. The reason for this is simple. If the enemy can cause the warhead to detonate prematurely, the missile will be destroyed. In contrast, however, jamming the guidance system may only result in deterioration of missile performance rather than complete failure. To completely abort the missile, the guidance system must be jammed for a considerable period of time; otherwise it may be able to correct for the interference.

There are a number of basic techniques that the fuze designer can use to eliminate or reduce the effects of enemy jamming. Among these are frequency diversity, increased fuze power output, use of unique fuze signals, dual fuzing, and delayed arming. The extent to which these techniques are implemented depends primarily on the weapon to be fuzed, cost, added complexity, etc.

The discussion, thus far, has been concerned with radio-type proximity fuzes. Certain types of nonradio proximity fuzes, such as barometric and inertial, are, by the nature of the phenomena on which they operate, difficult to jam. Although these types of fuzes are not as advanced as radio-type fuzes at the present time, it is conceivable that in the future they may be developed to the point where they could be used in many fuzing applications.

One other counter-countermeasures consideration, though not a design factor, is security. An enemy must not gain knowledge of a system before it is used against him. If a new type of fuze is developed and used in combat, the enemy must first ascertain what kind of fuze it is and what type of countermeasures will be effective against it. He must then design proper jamming equipment, get it into production, train personnel in its use, and finally, get it into the field. It is obvious that this can be greatly speeded up if the enemy has prior knowledge of a fuze before it is introduced into combat.

2-2.4.3 (U) Compatibility With Weapon

The fuze designer is part of the weapon system team. To design a fuze for a particular weapon, the designer must be thoroughly familiar with the requirements and characteristics of the weapon.

Before the design of a fuze is started, such things as the specific application of the weapon, its ballistic characistics, warhead characteristics, environment, accuracy, reliability, and safety requirements must be known. Also, the dimensions and shape of the weapon, the location and dimensions of the area allocated for the fuze, and the maximum permissible weight of the fuze must be known. From these data, the fuze designer must determine what type of fuze is best suited for the weapon. In many instances, an existing fuze with modifications may be adequate. In other instances, a completely new fuze will have to be developed.

When considering fuzes for guided missile applications, the fuze designer must be aware of certain additional weapon characteristics. For instance, the type of guidance system used and its accuracy must be known. It is possible that certain guidance information may be suitable for fuzing. The same applies for the missile power sources. It may be possible to use the missile power source to provide all or some of the power required to operate the fuze. The fuze designer must also know the dimensions and maximum movement of missile control surfaces. The movement of such surfaces may interfere with the radiation pattern of the fuze, causing spurious fuzing signals.

From the very beginning of a fuze development program the fuze designer must always keep the required characteristics of the weapon in mind. Many times these requirements are modified or changed. Therefore, constant communication among the fuze designer and other system designers is vital. The fuze designer's responsibility is to develop the best fuze possible within the specified requirements for the weapon, not simply the best fuze possible. It is unrealistic to devote time and money to develop a fuze that far exceeds the accuracy and reliability of the weapon itself.

2-2.4.4 (U) Human Engineering

A fuze should not be designed on the basis that a trained engineer will operate it. After the fuze leaves the factory, it will be operated by relatively less skilled personnel. This normally results in some deterioration of performance. Also, because a fuze is a combat weapon, the operator will probably be under great stress at the time he is using the fuze. What may be a simple procedure in the laboratory, for example, turning a knob to set a desired function height, is not always a simple and automatic task in the field.

Human engineering principles must also be applied to the production of a fuze. Again, a trained engineer will not perform the procedure required to construct, align, and test the fuze. These will be performed by relatively unskilled personnel doing simple, repetitive tasks. The fuze designer should try to use circuits that require simple and straightforward alignment or adjustment procedures. He should avoid the "mystery" circuits, which when constructed, do not operate as the original design indicated because of feedback paths and distributed parameters that are not indicated on the schematic or wiring diagrams.

2-2.4.5 (U) Production and Cost

The fuze designer must consider production from the very beginning of a fuze development program. Early consideration of production many times avoids costly redesign, delays, and possibly the abandonment of a project in which much time and effort have been invested. Because it is impossible for the fuze designer to foresee every problem that may arise in manufacturing a new fuze, close liaison with the production engineer is imperative.

The cost of a fuze is a complicated factor It involves development costs, manufacturing costs, maintenance costs, and user costs. All of these costs are related and cannot be considered separately. For example, increased reliability may increase development costs but lower user costs because fewer missiles may be required to perform a tactical mission. More time devoted to selection of ready available materials and components may reduce manufacturing costs considerably. Generally, the fuze designer can keep the total cost of a fuze down by using standard components, materials and hardware, and simple straightforward circuits as far as practicable.

(C) GLOSSARY

The terms and definitions included herein have generally been limited to those of special concern to fuze technology. Terms marked with an asterisk (*) are defined in this glossary.

acoustic fuze. A fuze that is caused to function by the sound energy emitted by or reflected from a target.

activation time. The time between an activation signal and the achievement of the desired conditions.

active battery. A battery that generates electromotive force from the moment it is manufactured. Sometimes called a ready battery.

active fuze. A fuze that emits energy and is triggered by the portion of this energy that is reflected back to the fuze from the target.

active life. The time during which a device operates within specified performance limits.

afterburning. Combustion of residual rocket motor fuels occurring after nominal completion of burning.

Alpha fuze. A microwave FM/CW fuzing system* for use against air targets. The fuzing signal is derived from information contained in the Doppler sidebands of a suppressed subcarrier, which is the third harmonic of the modulation frequency. (Confidential)

ambiguity. The range error that occurs in a pulsed radar system when a transmitted signal strikes a distant target and returns during the interval following the succeeding transmitted pulse.

antivehicular influence fuze. An influence fuze* that activates an implanted land mine by sensing the approach or presence of a vehicle, usually a tank. The most common influences proposed to activate this type of fuze are magnetism, vibration, pressure, radioactivity, heat, and eddy currents.

aqueous battery. A battery in which the electrolyte is a water solution.

armed. The condition of a fuze normally required to permit the fuze to function upon receipt of a triggering signal or upon lapse of proper time interval.

arming. Removing of the mechanical and/or electrical barriers to the operation of the explosive train in a fuze. Changing from a safe condition to a state of readiness for functioning.

arming delay. The time delay between missile launching, bomb dropping or tossing, or mine emplacement, and completion of arming*. *See:* **separation distance.**

arming programmer. An electromechanical or electronic device which is part of the arming system in complex missile fuzes. It generates certain electrical outputs in a specified sequence when provided with a given set of input signals. The electrical outputs cause arming actions in other parts of the system. Input signals may be command signals from a remote location, signals from built-in timing devices, or signals generated by launching, change in altitude, etc.

balanced discriminator. A discriminator in which no output is produced when the input signal is of uniform spectral density.

barometric fuze. A fuze that is activated by ambient state air pressure.

capacitance fuze. A fuze that operates on the change in effective capacitance between parts of the fuze, or between fuze and projectile, as the fuze approaches the target.

cigarette fuze. A nickname for a type of capacitance fuze of unusually small size.

Cobra fuze. A microwave FM/CW fuzing system* for use primarily against ground targets. Basic operation is similar to that of the Delta fuze*, except that random noise is used to modulate the RF carrier. The use of an unpredictable, aperiodic function for modulation greatly enhances the counter-countermeasures capabilities of the fuze. (Confidential)

command arming. An auxiliary mechanism used to arm a fuze from a remote control station. The arming command is an electromagnetic signal transmitted from the control station to the fuze. In mine fuzing, command arming is often used to disarm, as well as arm, the fuze.

command fuze. A fuze that functions upon receipt of a command transmitted to it from a remote control station.

computer fuze. A digital or analog device that computes the optimum time for warhead detonation from information provided from outside the fuze.

contact fuze. A fuze in which the primary initiation results from actual physical contact with a target. Sometimes called impact fuze when appreciable relative velocity exists at contact between fuze and target.

continuous-rod warhead. A warhead from which linked steel rods are exploded in a continuous, unfolding ring concentric with the warhead.

CW Doppler fuze. A fuze in which operation depends on the difference between the frequency of the fuze transmitter and the frequency of the received signal reflected from a target as the fuze approaches or recedes from the target (Doppler effect).

decision and firing circuits. The circuits of a fuze that distinguish between an actual fuzing signal and spurious residual, or countermeasures signals, and apply a firing signal to the warhead only when an actual fuzing signal is received.

Delta fuze. A fuze using a microwave FM/CW spectrum-ratio*, distance-measuring system. (Confidential)

D-factor. A measure of the ability of a fuze to reject a jamming signal. It is the ratio of the power required to jam the fuze to the fuze output power.

dud. A fuze that has failed to operate. Late functions* of a fuze is sometimes considered dudding.

early function. A fuze function that occurs after normal arming but too soon to be considered a proper function*. (Often caused by intrafuze microphonics.)

electrostatic fuze. A fuze that is triggered by electrostatic field effect(s).

escapement. A mechanical device that regulates the speed at which a mechanism, e.g., a clockwork, operates.

explosive motor. A small, one-shot explosive device used to move, lock or unlock some other device such as an S & A device, or operate an electric switch.

explosive switch. A packaged unit containing an explosive motor* and the switch it operates.

false alarm probability. The probability of a fuze functioning on noise when an actual target signal is not present. More generally, the probability that an effect is due to extraneous rather than intended causes.

FLAF (FLAH, FLAJ, etc.) Florida amplifier type F, etc. *See:* **integrating amplifier.**

Florida amplifier. *See:* **integrating amplifier.**

FM/CW fuze. A frequency-modulated, continuous-wave radio proximity fuze*. (Confidential). *See:* **Alpha, Delta, and Cobra fuze.**

fragmentation warhead. A warhead designed to spray high-velocity fragments of relatively uniform size.

frequency-modulated, continuous-wave fuze. A radio proximity fuze that employs frequency modulation techniques to cause warhead detonation.

function height. *See:* **height of burst.**

guidance fuze. A fuze that derives all information for fuzing from the missile guidance system.

hard limiter. A limiter* that approaches the ideal in performance.

height of burst (HOB). The altitude above a target (usually the ground) at which a fuze functions or is intended to function. Also called function height.

height of burst (HOB) selector. A switch usually operated by a knob or simple tool, that permits presetting the desired height of burst into a fuze.

impact fuze. *See:* **contact fuze.**

induction field fuze. A radio proximity fuze that is triggered by the detected effect of the target on the near-zone (induction) field of the fuze transmitter.

inertia generator. A transducer that converts mechanical energy into electrical energy, the mechanical energy being derived from the acceleration or deceleration of a mass. Many designs are possible. Those most commonly proposed involve electromagnetic induction or piezoelectric effects.

influence fuze. A proximity fuze*. The term "influence fuze" is used extensively in land mine applications.

integrating amplifier. An amplifier in which the output is approximately proportional to the time integral of the input signal. Sometimes called Florida amplifier, intelligent amplifier, or M-wave selection circuit.

intelligent amplifier. *See:* **integrating amplifier.**

J_2 fuze system. An FM CW fuze* in which the detector is tuned to the second harmonic of the modulation frequency. (Confidential)

J_3 fuze systems. An FM CW fuze* in which the detector is tuned to the third-harmonic of the modulation frequency. (Confidential)

late function. In surface target applications, a fuze function lower than the normal distribution of function heights. In air target applications, a function beyond a statistically expected burst position. Late function is sometimes considered a dud.

limiter. A nonlinear device with an output that is limited to some definite amplitude. Ideally, all output signals of lower amplitude are unaffected.

loop gain. In an active proximity fuze,* the maximum attenuation that can be inserted between the terminals of the transmitting antenna and the terminals of the receiving antenna without preventing the fuze from functioning

lucky. A piezoelectric ceramic element, usually of barium titanate, that generates an electrical pulse to fire a detonator on impact with a target. (Confidential)

Michigan height. The theoretical height at which a CW Doppler fuze* would function when approaching ground at an optimum velocity with optimum orientation of missile. Sometimes termed Michigan sensitivity.

modulated pulsed Doppler fuze. A pulsed Doppler fuze* in which intermittent operation of the fuze transmitter oscillator, at a prescribed repetition rate and pulse width, is controlled by a separate pulse modulator. (Confidential) *See:* **self-pulsed Doppler fuze.**

MPD. modulated pulsed Doppler fuze*.

multiple fuzing. The combining of fuzes into a network on a single round of ammunition.

multipurpose fuze. A fuze designed for detonating warheads of differing burst characteristics.

M wave. The signal produced in a Doppler-type fuze as it approaches a ground target or approaches and passes (or impacts) an airborne (or in-space) target.

M-wave selection circuit. *See:* **integrating amplifier.**

nonradio proximity fuze. A proximity fuze that depends on other than radio phenomena for its operation. Such phenomena include optical radiation, barometric pressure, and electrostatics.

"no stored energy". A safety concept that a primary safety and arming device should not depend for operation on cocked springs, explosive motors, or other types of energy stored prior to firing.

optical fuze. A nonradio proximity fuze* that utilizes optical principles to sense proximity to a target; including fuzes that operate in the visible, infrared, and ultraviolet portions of the electromagnetic spectrum.

parallel fuzing system. A multiple fuzing* system in which two or more fuzes are connected in parallel. Warhead detonation occurs when any one of the fuzes operates.

passive fuze. A fuze that is triggered by energy emitted by the target itself (e.g., an infrared fuze triggered by the infrared radiation emitted by a jet aircraft) or by the loss of background energy caused by obscuration or scattering by the target (e.g., a passive optical fuze triggered by the loss of skylight due to an intervening aircraft).

proper function. The operation of a fuze as intended.

proximity fuze. A fuze that initiates warhead detonation by sensing the presence, distance, and/or direction of a target.

pulsed Doppler fuze. A modification of the CW Doppler fuze*, in which the fuze transmitter oscillator emits RF energy intermittently at a prescribed repetition rate and pulse width. Unlike pulsed radar, reception of a signal reflected from a target can occur only during the period that the fuze is transmitting. (Confidential)

PTTB. Code designation (progression-time-transverse-bomb) for a bomb fuze with an integrating amplifier. "Transverse" indicates that the fuze pattern has strong lobes approximately at right angles to the axis of the bomb.

pulsed frequency-modulation fuze. A combination FM/CW fuze* and SPD fuze* in which the Doppler signal is recovered from pulse samples. (Confidential)

pulsed radar fuze. A radio proximity fuze* which is a miniaturized pulsed radar system. It measures the time required for an electromagnetic wave to traverse the distance from the transmitter to the target and return. It detonates the warhead when a predetermined sufficiently short time interval is reached. (Confidential)

R-1B klystron. A special purpose klystron microwave tube developed specifically for use in guided missile FM/CW fuzing applications.

radioactive fuze. A proximity fuze that is triggered by radioactivity (alpha, beta, or gamma rays).

radio proximity fuze. A proximity fuze that depends for operation on reception of energy in RF part of the electromagnetic spectrum.

reaction grid detector (RGD). An oscillator in which grid bias changes with oscillator load. Used extensively in CW Doppler fuzes*.

ready battery. Same as active battery*.

repeater jammer. A jammer that receive a fuze signal, amplifies it, and transmits the amplified signal back to the fuze as a jamming signal.

reserve battery. A battery that is inert until it is activated.

RIF fuze. Radio induction field fuze. *See:* **induction field fuze.**

S & A device. Safety and arming device*.

safety and arming device. A device designed to prevent fuze function (and, sometimes, independently to prevent warhead detonation) under foreseeable conditions of storage, transportation, and preparation for use, and to permit fuze function and warhead detonation only under predetermined operating conditions.

self-destruction. Destruction of a round of ammunition by a device within the fuze at a predetermined time or distance after arming, usually to avoid compromise or damage to friendly property or personnel, when proper function* cannot be achieved.

self-pulsed Doppler fuze. A pulsed Doppler fuze* in which intermittent operation at a prescribed repetition rate and pulse width is accomplished by setting the time constants of the fuze transmitter oscillator circuit to cause intermittent, or squegging, operation. (Confidential) *See:* **modulated pulsed Doppler fuze.**

semiactive fuze. A fuze that is triggered by the energy reflected from a target which is illuminated by a friendly source; e.g., reflection of RF energy to a rocket fuze from a target illuminated by the radar of the launching aircraft.

semipassive fuze. A fuze that is triggered by the energy reflected from a target that is illuminated by a source not under control of either friend or foe; e.g., reflection of the sun's radiation by a target to an optical fuze.

sensitivity pattern. A hypothetical surface surrounding a missile representing the locus of target positions for fuze function.

separation distance. The distance between a round of ammunition and the person or device that fired, tossed, or dropped it, when the fuze of the round becomes armed. *See:* **arming delay.**

sequential events setback mechanism. A fuze safety mechanism which is designed to provide safety by discriminating between firing setback* and setback due to poor handling. It consists essentially of interlocking elements that must be moved in a particular sequence by a launching acceleration of appropriate magnitude and duration to accomplish a particular final motion.

series fuzing system. A multiple fuzing* system in which two or more fuzes are connected in series. Warhead detonation occurs only if all fuzes operate.

series parallel fuzing system. A multiple fuzing* system in which two or more series fuzing systems* are connected in parallel, or two or more parallel fuzing systems* are connected in series.

setback. The relative rearward movement (or force) of component parts of a fuze undergoing forward acceleration at launching. These phenomena are often used to cause or allow events which participate in the arming and eventual functioning of the fuze.

setback leaves. *See:* **sequential events setback mechanism.**

shelf life. The storage time during which a fuze or a fuze component remains operable and safe. The specified shelf life for fuzes is generally between 6 and 20 years.

shock-wave fuze. A fuze that is initiated by shock-wave phenomenon. (Confidential)

short-pulse radar fuze. A pulsed radar fuze* having a pulse duration of about 20 nanoseconds or less. (Confidential).

signature. The characteristic signal in a fuze, peculiar to each type of target, which may enable the fuze to sense and differentiate targets from background noise and from each other.

"soft" limiter. A limiter* that is noticeably not ideal in its operation. The output is somewhat reduced even for signals below the nominal limit, and the output increases somewhat for signals greater than the limit.

slotted-waveguide antenna. A section of waveguide with slots cut in it to radiate microwave energy into space.

SPD fuze. Self-pulsed Doppler fuze*.

spectrum-ratio fuzing system. A fuzing system in which the discriminator circuit measures the shift in the probability distribution of the instantaneous difference frequency between transmitted and received signals to determine when the target is at fuze-function distance. (Confidential)

spin breaker. A mechanical device, operated by centrifugal force, that breaks the electrolyte ampule of one kind of reserve battery* to permit flow of the electrolyte between the battery plates.

springbok. A particular radio command arming system* proposed for mine fuze applications.

squegging. The periodic self-quenching of an oscillator.

thermal battery. A reserve battery* that is activated by heat.

thermal fuze. A fuze that is triggered by a change in temperature.

time delay computer. A computer used within a fuze which, after receipt of a proper triggering signal, computes the delay in warhead activation that results in optimum warhead effectiveness. Not considered a true computer fuze.

transverse bomb fuze. An electronic proximity fuze designed for nose mounting in a bomb; it is distinguished by a dipole antenna normal to the axis of the bomb.

trembler switch. A very sensitive resonant-type electrical switch (using a mass-spring combination) designed to operate on very small forces of acceleration or deceleration.

TRUD. "Time remaining until dive" in missile applications having appropriate trajectories.

white noise. Noise that contains constant energy per unit bandwidth throughout its frequency spectrum.

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